AN INTEGRATED MODEL FOR PRODUCTION LINE BALANCING PLANNING

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ABSTRACT

Automobile manufacturing is one of the most important industries in the world. The production line is one of the main supply chain of this industry. The production line consists of four shops. The shops include many stations. Each station has several variables such as car parts, materials, task's number, cycle time, number of workers, etc. The task's numbers depend on the number of car parts and pieces depending on the type of car. To complete tasks at the station, the workers need time to weld the pieces to the structure of the car. The cycle times of these tasks are not equal in each station and shop. The unbalance cycle time stations create queuing and idle time. The Production Line Balancing Problem (PLBP) is one of the main focuses of research in automobile manufacturing. The problem in PLBP is the queuing and the idle time during task achievement that is an obstacle to efficient assembly line. Moreover, the unbalancing problems also include the tasks number and the number of workers among the stations. In addition, the unbalancing problem includes the unbalance between the quantity of the customers demand and the production quantity, which are the Production Line Planning (PLP) problems. This study used a new method to solve these problems. The new method is the Multi-Objectives Model (MOM) combined with the Genetic Algorithm (GA) system (MOM/GA). Furthermore, the Simulation Model (SM) is used to solve the PLP problem to achieve the customer order by increasing the quantity of production. The new approach is called Hybrid Model of the Production Line (HMPL) which is a combination of MOM, GA, and SM. This approach is employed to solve the production line problems and to develop the efficiency of the production line. As a result, the Mixed Model (MM) that combines the MOM and GA is developed to solve the PLBP and efficiency of the Production Line System (PLS) in order to reduce the queuing and the idle time to obtain the best balance among the stations. Also the MM is applied to PLS to re-regulate the tasks' number and re-distribute the jobs to the workers among the stations in order to obtain the optimum solution. On the other hand, the SM is applied to solve the planning problem to make new plans then to make several strategies to solve the PLP problem and to achieve the customer orders. The aim of this study is to combine MM and SM to develop the efficiency of the production line and to solve both problems by using the output of MM as an input for SM and vice versa. This is a new method to obtain the best or the optimum balance among the stations and also between the quantity of customers demand and the production quantity. The method increased the ratio of production and reduced the queuing and idle time by minimizing the queuing and idle time and maximizing the productions, as well as balancing the tasks' number and distributing the jobs to the workers evenly.

ABSTRAK

Pengilangan keluaran automotif merupakan salah satu industri yang terpenting di dunia. Operasi pengilangan automotif ini juga merupakan salah satu daripada rantaian bekalan utama bagi industri ini. Operasi di kilang kebiasaannya dibahagikan kepada empat pusat utama. Bagi setiap pusat ini pula terdapat bahagian-bahagian lain yang dikenali sebagai stesen. Untuk setiap stesen ini terdapat beberapa parameter penting seperti komponen kereta, bahan-bahan, nombor tugas, masa kitaran, bilangan pekerja, dan lain-lain yang bergantung pula kepada bilangan alat-alat ganti kereta dan model kereta. Untuk menyelesaikan tugasan di stesen ini, para pekerja memerlukan masa tertentu untuk mengimpal kepingan alatan pada struktur kereta. Masa menyiapkan tugasan ini tidak sama bagi setiap stesen-setesen ini. Disebabkan masa melakukan sesuatu tugasan yang berbeza ini menyebabkan wujudnya keadaan menunggu giliran dan masa tidak produktif. Masalah ketidakseimbang ini (PLBP) merupakan salah satu fokus utama penyelidikan dalam industri pengilangan automotif. Masalah giliran dan masa yang tidak produktif menyebabkan pencapaian tugasan menjadi penghalang kecekapan pemasangan kenderaan. Selain itu, masalah ketidak seimbangan ini juga berlaku dalam pengagihan bilangan tugasan dan pekerja di stesen-stesen berkenaan. Ia juga menyebabkan ketidak seimbangan diantara kuantiti permintaan oleh pelanggan dan kuantiti pengeluaran oleh kilang. Kajian penuelidikan ini dijalankan dengan menggunakan metod baru bagi menyelesaikan masalah-masalah yang dinyatakan di atas. Kaedah-kaedah baru ini dikenali sebagai Model Multi-Objektif (MOM) yang digabungkan dengan Algoritma Genetik (GA) dikenali MOM/GA. Disamping itu juga, Model Simulasi (SM) digunakan untuk menyelesaikan masalah PLP bagi memenuhi permintaan pelanggan dengan meningkatkan kuantiti pengeluaran. Pendekatan baru ini dikenali sebagai pemodelan Hibrid Pengeluaran (HMPL) yang merupakan gabungan MOM, GA, dan SM. Pendekatan ini digunakan untuk menyelesaikan masalah-masalah pengeluaran dan meningkatkan kecekapan pengeluaran kenderaan. Juga Model gabungan (MM) digunakan untuk mengawal selia bilangan tugasan dan mengagihkan semula tugasan kepada pekerja-pekerja di stesen-stesen berkenaan bagi mendapatkan penyelesaian optimum. SM juga digunakan untuk menyelesaikan masalah perancangan bagi menilai beberapa strategi untuk menyelesaikan masalah PLP dan untuk menmenuhi permintaan pelanggan. Tujuan kajian ini juga adalah untuk menggabungkan MM dan SM bagi meningkatkan kecekapan pengeluaran dan untuk menyelesaikan masalah kedua-duanya dengan menggunakan output MM sebagai input untuk SM dan sebaliknya. Ini adalah satu kaedah baru untuk mendapatkan yang terbaik atau keseimbangan yang optimum di kalangan stesen-stesen dan juga antara kuantiti permintaan pelanggan-pelanggan dan kuantiti pengeluaran. Kaedah ini berjaya meningkatkan nisbah pengeluaran dan mengurangkan masa menunggu dan masa tidak produktif dengan meminimumkan masa menunggu dan masa tidak produktif. Ia juga berupaya memaksimumkan pengeluaran kilang dan mengimbangi bilangan tugasan dengan mengagihkan tugasan secara sama rata.

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Q	Total Queuing Time in production Line
P	Number of Shop
S	Total Number of Stations
CTs	Cycle Time at stations
X	Variable for Each Task
DT	Idle Time
W	Number of Worker
Nw	Limitation Number of Workers for each station
Tw	Total Number of Workers
Nws	Number of Workers in Each Station
t_n	Tasks number
PTT	Processing Tasks Time
Wn	Number of Workers append
No.T	Number of Tasks
RJS	Ratio of the Jobs of each station.
AVCT	Average Cycle Time
D	Difference in time among stations (Queuing and Idle Time)
Pro	Quantity of the production
NWADD	Number of Workers Add to production line
TTS	Total Time Saving
NWT	Total Time Can the Company Work Per Day
CPL	Capacity of the Production Line
QD	Quantity of Demand

ATPOC	The Average Time to Produce One Car
TJTEW	Total Jobs Time for Each Worker in each station
NWES	Number of Workers of Each Station

LIST OF ABBREVIATIONS

ALB	Assembly Line Balance
AS	Assembly Shop
BDP	Bounded Dynamic Programming
BS	Body Shop
CPL	Capacity of the Production Line
CS	Chassis Section
CT	Cycle Time
CTs	Cycle Time Station
DSS	Decision Support System
DSSPL	Decision Support System for Production Line
EC	Evolutionary Computation
FS	Finally Section
GA	Genetic Algorithm
GP	Goal Programming
HM	Hybrid Model
HMPL	Hybrid Model of the Production Line
INT	Inventory Theory
JIT	Just In Time
LP	Linear Programming
MM	Mixed Model
MMOS	Mixed Model Optimization Solution
MOM	Multi Objectives Model
NLP	Nonlinear Programming

NN	Neural Network
OR	Operation Research
PL	Production Line
PLBB	Production Line Balancing Problem
PLP	Production Line Plan
PLS	Production Line System
PS	Paint Shop
PSO	Particle Swarm Optimum
PTT	Processing Tasks Time
QA	Queuing Analysis
SA	Simulation Annealing
SCM	Scheduling Model
SD	System Dynamic
SM	Simulation Model
TES	Test Shop
TS	Trim Section

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

The automobile manufacturing is one of the most important industries to date established in Germany in 1886. The industry has been relying on intensive labor since its inception. Due to the durability of product life cycles and fierce competition, the automobile industry has moved towards cost-effective products i.e., they produce a variety of product types. Moreover, these automobile companies face tough challenges in automobile production such as reducing time of the production line and developing production plan that meets customers demand (Toshio et al., 1996; Gnoni and Lavagilio, 2003; Mehrdad, 2004).

In the automobile manufacturing system, one of the areas under consideration is Production Line Balancing Problem (PLBP) which distributes the total workload among manufacturing stages (Toshio et al., 1996). There are many researchers who studied on the problems regarding PLBP and Production Line System (PLS) in order to obtain the best solution (Minh and Soemon, 2008). These important problems present the first major problem of the production line.

Production Line Plan (PLP) is an important requirement of the automotive manufacturing system to ensure the optimum balances between the quantity of customers demand and the productions quantity, by producing a new management plan. Sometime the managers of the production line cannot satisfy the customers due to gap between the quantity of productions and the demand (Gnoni and Lavagilio, 2003). This problem presents the second major problem of the production line.

There are several mathematical models that have been developed in the automobile manufacturing industry such as linear programming (LP), queuing, probability, simulation models, scheduling, neural network, system dynamic, and statistics (Dalvi and Guay, 2009; Resano and Luis, 2009; Birkan and Cathal, 2012.). Many of these models were developed based on decision support system that is used for assisting the management to make decision (Poon et al., 2011). Nowadays, there is a trend to develop a hybrid model which can be more efficient in solving complex problems (Amir and Farhad, 2006; Burcin et al., 2011). In this study, two distinct models are developed to solve PLBP and PLP problems. The two models are Multi Objectives Model (MOM) and Simulation Model (SM). Further, a combination of these two models will form a Hybrid Model of Production Line (HMPL). It is a desire that HMPL will be a more powerful model that could solve a wider scope of problems for producing an optimum plan for the production line. The study will also present a Genetic Algorithm (GM) system that is embedded with MOM for obtaining an optimum solution. This approach is still at an infancy stage among researchers.

In this study, MOM/GA is used to solve the queuing problem of the production line which include several stations that consists many operations. The developed model will be used to reduce the queuing among these stations, hence, resulting in minimized cycle time, and maximized workload (Amir and Farhad, 2006). On the other hand, SM approach was used to solve the planning problem by improving PLP and ensuring optimum balance between the quantity of the customer's demand and production quantity (Ruey-Shun, C. and Kun-Yung, 2002).

The developed Decision Support System for Production Line (DSSPL) for this study is an ultimate integration of MOM, GA, SM, and HMPL. The Decision Support System (DSS) is an advanced method that applies these models to develop a plan and system of the automobile manufacturing.

1.2 SYSTEM DESCRIPTION

The production line in the automobile manufacturing system of plant under study consists of four different shops that are Body Shop (BS), Painting Shop (PS), Assembly Shop (AS) and Test Shop (TES). Each shop composes of many stations which performs different tasks. The semi-finished manufactured products have to move in pre-planned sequence among these shops. Figure 1.1 shows the production line of the automobile manufacturing system. It starts initially with the body shop, then paint shop, later assembly shop, and finally the test shop (Hicom, 2010). The more detail of production line of automobile manufacturing will be described in Chapter 3.

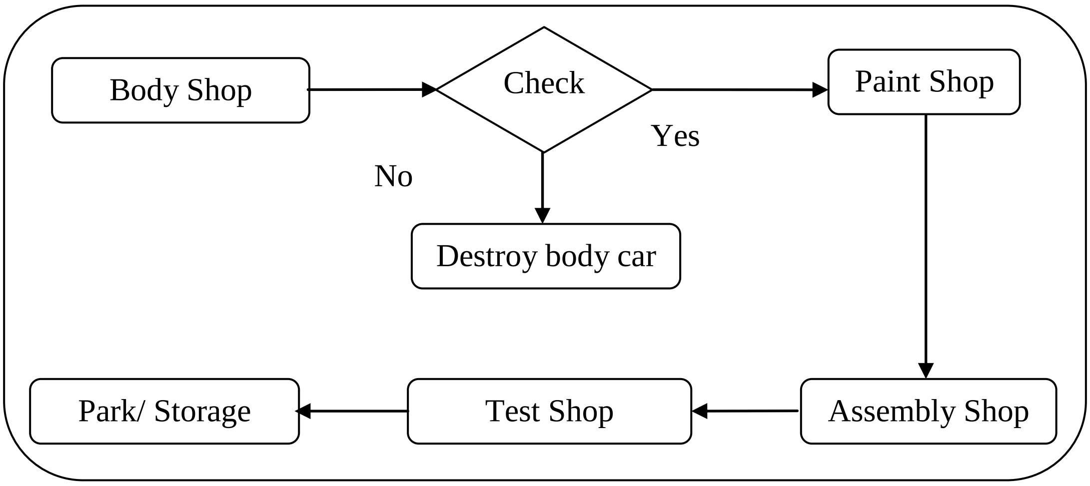

Figure 1.1: Production line of automobile manufacturing system

Each shop in the production line has an assembly and sub-assembly line. The parts are pre-prepared in the sub-assembly before they were sent to the assembly line for processing. For the assembly line to perform at an optimum level, the operation at the station must be balanced with respect to its cycle time. Figure 1.2 shows the assembly line and the sub-assembly of all shops of the production line system (Christian et al., 2009; Junfeng et al., 2011).

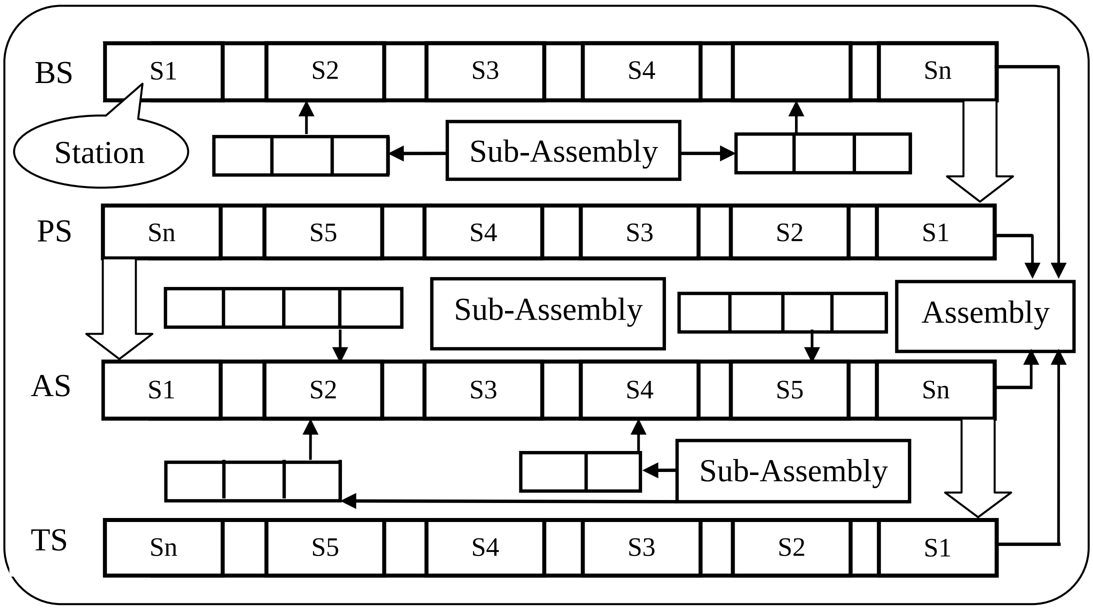

Figure 1.2: Production line of assembly and sub-assembly line

1.3 PROBLEM BACKGROUND

The case under study focuses on two main problems of the production line of the automobile manufacturing system. Both of the problems are production line balancing and production line planning that will be explained in more detail in the next section.

1.3.1 Problem Description

The production line under study focuses on two main problems namely, production line balancing and production planning, balancing problem occur when not all stations are able to complete all tasks at the same time (Christian and Armin, 2009). As a result, it causes a congestion problem at the production line and the resources are under utilized. The problem is illustrated in more details as shown in Figure 1.3 which contains three scopes with the L1 represents processing tasks time, L2 represents number of tasks, and L3 for number of workers.

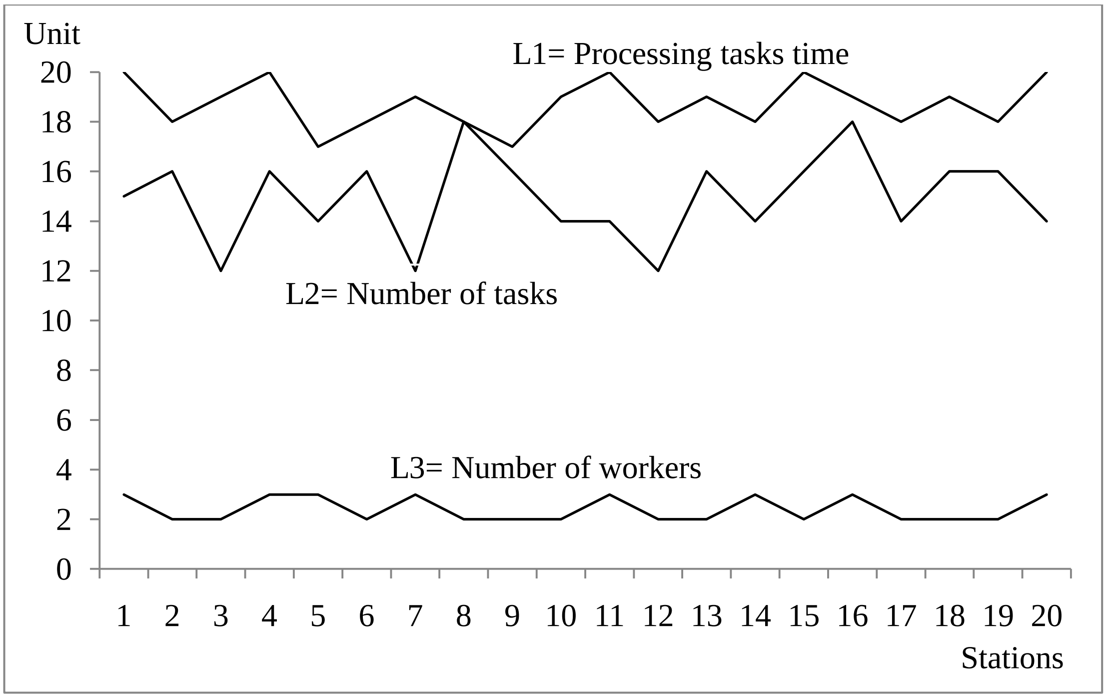

Figure 1.3: Unbalance problem of the PLS

Production line plan and scheduling strategy are important to the production managers because both are used as a basis to make decision on production quantity. The plant has a few standard plans for different quantities of production capacity. The plant however will face a problem when the quantities of demands are different from the company`s allocated standard (Gnoni and Lavagilio, 2003). The current practice in the company is not flexible enough to accommodate production the changes of quantity of demand. Figure 1.4 illustrates this problem, where L1 represents the quantity of demands and the L2 represents the quantity of products. The figure shows that the quantity of demand is more than the quantity of production. The gap demonstrets that the plant is unable to fulfill the demand of customers.